Anthomyidæ.[8] It is a critical revision of the genera of the family, with especial consideration of the male genital apparatus, and all the plates represent hypopygia or lobes of the fifth ventral segment. The authors consider the family in the sense of Girschner, including most of the Muscidæ. In the supplementary part are descriptions of many new species, mostly from Russia.

The progress of entomology in South America is unfortunately slow, and for this reason we welcome each new elementary treatise from that quarter as an encouragement for the local naturalists to collect and study their insects. A new work of this character is by Dr. C. E. Porter on the Myriopods of Chili.[9] He gives an illustrated account of the structure and habits of myriopods, and follows with an annotated list of the 64 species so far described from Chili. Many of the genera are different from those of our country, and several are peculiar to Chili.

The anatomical part of the 34th (1912) volume of the *Zoologisches Jahrbücher* is more than ordinarily occupied by entomological articles. Mr. Edw. Schoenemund gives a descriptive and biological study of the larvæ of the three large European Perlas,[10] with notes on the anatomy of the respiratory and digestive systems, and the development of the sexual organs.

Mr. S. Surlov has an article on the salivary glands in the head of some Orthoptera, especially *Mantis*[11] and their relation to similar glands in Myriapoda.

Dr. H. Mammen gives a comprehensive study of the comparative morphology of the stigma in various Hemiptera,[12] both in Heteroptera and Homoptera. He finds that in most Hemiptera there is but one muscle to each stigma whose contraction closes the slit, but in a few forms, two or three muscles occur.

Dr. W. Baunacke has a long article on the sense organs of certain aquatic Hemiptera of the family Nepidæ.[13] These organs on the venter are considered to be organs of orientation.

Mr. E. Foerster gives the results of a study of the comparative anatomy of the sting of various ants,[14] and traces the homologies.

Nathan Banks

[8] "Die Anthomyiden," *Abh. Kaiserl. Leop.-Carol., Deutsch. Akad. Naturf.*, XCV. (No. 2), pp. 55–358, 35 pls., 1912.

[9] "Introduccion al estudio de los Miraopodos," Santiago, 1911, 68 pp.

[10] "Zur Biologie und Morphologie einiger Perla-Arten," pp. 1–56, 2 pls.

[11] "Uber die Kopfdrüsen einiger niederen Orthopteren," pp. 97–120, 3 pls.

[12] "Ueber die Morphologie der Heteropteren und Homopteren-stigmen," pp. 121–178, 3 pls.

[13] "Statische Sinnesorgane bei den Nepiden," pp. 179–346, 4 pls.

[14] "Vergleichend-anatomische Untersuchungen über den Stechapparat der Ameisen," pp. 347–380, 2 pls.

SPECIAL ARTICLES

PALMESTHETIC BEATS AND DIFFERENCE TONES[1]

In publishing the results of my experiments on palmesthetic difference sensibility,[2] I did not take up the question whether the discriminations with which we were dealing were of rates of succession of discrete sensations, or of differences in the characters or quasi-characters of continuous sensations. That this question must be raised is of course obvious, since the vibration-rates of the forks I employed (between four and five hundred vibrations per second), are below the fusion limit as reported by Valentin,[3] von Wittich,[4] Schwaner[5] and others. The results of Preyer,[6]

[1] From the Psychological Laboratory of the Johns Hopkins University.

[2] Dunlap, K., "Palmesthetic Difference Sensibility for Rate," *Amer. Jour. of Physiol.*, XXIX., 108–114.

[3] Valentin, "Ueber die Dauer die Tasteindrücke," *Arch. f. Physiol. Heilk.*, XI., 438.

[4] Von Wittich, "Bemerkungen zu Preyer's Abhandlung über die grenzen des Empfindungsvermögens und Willens," *Pflüger's Archiv*, II., 329.

[5] Schwaner, "Die Prüfung der Hautsensibilität vermittelst Stimgabeln bei gesunden und Kranken," Inaug. Diss., Marburg, 1890.

[6] Preyer, W., "Die Grenzen des Empfindungsvermogens, etc.," 1868, 15.

Lalanne[7] and Mach,[8] giving the fusion limit far below the range I employed, throw doubt on the other results, and make it evident that there is somewhere in the determination a factor which has escaped attention by one group or the other of the experiments, or possibly by both.

The early observations were made with little reckoning of the troublesome psychological problems involved, and with no reference to the possibility which we must at present admit—that vibratory stimuli applied to certain portions of the skin may rouse sensations other than those of pressure, touch, temperature or pain: sensations of vibration, or palmesthetic[9] sensations, as they are provisionally designated. The former point we will consider below; the latter is of prime consequence.

If an observer assumes that when a tuning fork (the stem of it or some attachment to a prong) is applied to the skin the sensation aroused will be either that of mere continuous touch or pressure (we may leave out of account pain and temperature, as being easily discriminated from the other), as when the fork at rest (not vibrating, that is) is applied; or else of the discrete series of touches corresponding to the individual periods of the vibration, his observational problem will be comparatively simple. If the fork is perceived as being in vibration, the judgment will be "*discrete pulses,*" or "series of discrete tactual sensation"; if the fork feels as if not vibrating, the judgment will be "*fusion.*" In other words, the problem of observation is restricted to the question whether or not the fork can be perceived to be in vibration. This, we may reasonably infer, was actually the problem as understood by a number of the experimenters, and consequently the thresholds of fusion they reported were limited simply by the mechanical capacity of the forks (or whatever serial stimulation devices were employed) to produce a sufficiently intense vibratory stimulus.

When we admit the possibility that the vibration of the fork may produce a sensation which is not identical with the simple touch or pressure sensation, the problem becomes entirely different. It is now a question of determining the point (in rapidity of stimulus) at which the sensation enters, or the point at which it becomes a continuous sensation; or possibly we may have to make both determinations. That there are abundant clinical observations which go to show the existence of a palmesthetic sensibility not identical with touch or pressure, I pointed out in my first paper.

The forks with which I first worked (in the neighborhood of 440 vibrations per second) were too heavy for their length, and the vibration-feeling consequently feeble and of brief duration. I have since secured some forks which are better adapted to the work, being relatively more slender, and have carried on observations with these. They have prongs approximately 8×5.5 mm. in cross section, and 19 cm. long for c (128 per sec.) and 13 cm. long for c′ (256 per sec.). The c^2 forks of the same cross section, 9 cm. long, are less satisfactory. The forks have been fitted (by our mechanic) with tubular brass extensions to the stems, giving a total length from the crotch of 9.5 cm. The end of the extension is solid, with a diameter of 1 cm. Weights with clamp-screws are fitted to slide on the prongs so that the forks may be tuned from the original c and c′ down to the F and f below, by any required steps.

These forks were prepared primarily for the purpose of determining difference-sensibility in the octaves represented. This work has not been completed, but shows, so far, about the same threshold as was earlier obtained in the middle octave (approximately 10 per cent.). The present report is not concerned with this measure.

We early noticed that beats were palmesthetically perceived, and were as distinct and characteristic as auditory beats. With properly tuned forks, we found differential sensa-

[7] Lalanne, "Sur la durée de la sensation tactile," *C. R. de l'acad. des sci.*, LXXXII., 1314.

[8] Mach, E., *Sitzber. d. Weiner Akad.*, LI., 2, 142.

[9] The term was introduced in German, by Rydel and Seiffer in 1903.

tions, corresponding to auditory difference-tones. In arousing these, the two fork stems were firmly pressed together, and the circular end of one stem pressed lightly against the skin of the border of the palm; or the subject's finger tips were pressed lightly against the fork stem.

Fearing lest the phenomenon might be some peculiarity of the action of the physical couple corresponding to the "objective" difference tone, certain auditory experiments were carried out, as follows. A König resonator was tuned to the difference tone of one of the forks; it of course gave no response when the vibrating forks were not in contact, and it still gave no response when the stems were pressed together. Pressing both stems against a block of resonant wood failed to make the resonator respond, although the wood was brought within a few inches of the orifice of the resonator. A single fork tuned to the difference-tone and resonator, pressed against the wood in this way, evoked a loud response from the resonator, even when the fork was vibrating feebly.

It occurred to me that the point (in the scale of rapidity) at which the beats passed into a differential sensation might give a measure of the lower limit of palmesthetic sensibility, and that in any case the determination of this point was important. Here the difficulties were encountered.

As only an approximate determination was desirable at this juncture, one of the c′ forks was scaled in the steps b, a♯, a, g♯, g, f♯ and f, certified forks being at hand for these rates, giving differences with the other c′ fork of 16, 33 +, 42 +, 56, 64, 78 + and 85 + double vibrations.

In my own case, the determination is fairly certain. The beats are distinctly perceptible down to c′–g (64). At c′–f♯ (78 +) this discreteness begins to pass into a sensation comparable to that of another fork (*i. e.*, a continuous sensation), and at c′–f (85 +) this new sensation becomes unmistakable and definite, the beats entirely disappearing.

With still greater difference, the differential sensation persists, becoming less and less intense, as is the case with the sensations aroused by single forks of increasingly higher pitch.

In the first day's work with W., a graduate student, the results were exactly the same as those obtained from myself and were invariable. A month later his results were radically different. He still observed the differential sensation as like that from a low fork, but claimed that it was a matter of discrete pulses, differing from the beats of smaller differences only in rapidity. In fact, he now claimed that the single-fork stimuli, even from the 512 fork, gave series of discrete sensations, and further claimed that the auditory stimulus from the same fork produced the same sort of discrete sensations, corresponding to the air pulses. It should be said that W. is unmusical, but is a good observer.

My own observations fit in quite well with those of W., as regards the palmesthetic sensations, although the auditory sensations (beyond 40 vibrations per second) are always sensibly continuous. With best attention, the palmesthetic sensation (beyond 85 per second), is as continuous as the auditory, but nevertheless at certain other times it seems to be a discontinuous series. In my observations, however, there is a clear indication of the reason for this discrepancy. In one case I am attending to the sensation as it is; and in the other case to the fork thought of as an oscillating body—to the representation of visual or muscular sort—rather than to the actual presented sensation. Such training as my palmesthetic sensibility has received during the greater part of my life has probably been in the way of interpreting the sensations in terms of the vibrations represented as movements of some body; hence, even when I should be attending to the sensation I still incline to attend to the meaning instead. A large number of individuals undoubtedly tend to treat vibration in this way.

In attending to sounds, the interpretative tendency is not so strong, as the conditions are not so conducive to training in this direction. The special significance of sounds as

indicating oscillatory movement is more remote, and more easily detached from the sensation. This detachment was difficult for W., in the case of the tuning fork, because it was for him principally an instrument for the inscribing of curves for time-measurement: the sound of the fork signified its motion in space, and the intensity signified the amplitude of the sinusoidal line it could trace. This observation was made by W. and reported in practically the words I have used.

The results of observations made by several other subjects give about the same threshold as my own observations. One graduate student, J., perceived no beats at c′–g♯ (56), obtaining perfect fusion at that point, although in auditory experiments the fusion was not complete until 64 was reached. This subject at no time had tendency to confuse the sensation and the motion. He is quite musical.

Another graduate student, B., reported that he was constantly troubled by the "visualization" of the tuning-fork curve. He perceived clearly the discreteness of the beats up to c′–f♯ (78+), but beyond that point was unable to decide whether the sensation was or was not continuous.

D., an undergraduate student with previous training in palmesthetic work, and in discrimination of rates and in certain other sorts of psychological observation, obtained clear fusion at c′–f♯ (78¼) and undoubted discreteness at c′–a (42⅔). Between these points, there was doubt, and variation in his judgments.

It should be noted that the differential sensation (above about 80) is perceived as exactly like that due to the addition of a third fork, even by subjects who judge it to be a matter of discrete phases. The problem is, therefore, not to decide as to the character of the differential sensation merely, but concerns any vibration of the same rate.

The differential, when faint, may be made perceptible in a way quite similar to that in which the auditory differential is brought out, namely, by stimulating with the lower of the two forks alone for a moment, and then adding the higher; the resultant drop in the pitch of the clang is paralleled by the corresponding change in the felt vibration.

In the tests described herein, the forks were not audible, they being weakly excited, and used at a sufficient distance from the subject's head—at arm's length. In fact, they were scarcely audible when brought up to half the distance from the head.

After making these observations, I am compelled to view with suspicion the results of any simple observations on the threshold of discreteness and fusion in the palmesthetic or haphic realms (and, indeed, in the auditory realm also). I include my own observations in this suspicion, along with others, for while I may say that my observations have been very careful, they can not do more than establish a presumption. Mere observation ("introspection" in the sense of the word now happily becoming obsolete) is productive of no certain results; the measurements I have been describing are excellent vehicles for the demonstration of the fact, and I strongly recommend them to any one who is inclined to rely on the results of simple observation. These observations are not experimental in the proper sense of the word; but fortunately it is possible to apply experimental methods to the problem upon which they bear.

The palmesthetic difference sensation can not be wholly without significance for the theory of auditory perception. Although I have a bias against the "telephone" theory, I must admit that the perception of a difference in vibration rate by dermal or subdermal nerves, and the detection of a differential rate by these same nerves, seems to support strongly the assumption that differences in pitch of sound are not essentially connected with differences in peripheral nervous elements, but that the same cochlear nerve terminations may mediate different pitches, and the same pitch be mediated by different terminations.

KNIGHT DUNLAP

ECHINODERM HYBRIDIZATION

IT is my purpose to call attention in this note to certain facts, the consideration of which may do something toward bringing